NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

SALINITY AND SODIC SOIL MANAGEMENT

(Ac.)

CODE 610

DEFINITION

Management of land, water and plants to reduce accumulations of salts and/or sodium on the soil surface and in the crop rooting zone.

PURPOSE

Improve soil health by reducing:

- salt concentrations in the root zone
- problems of crusting, permeability, or soil structure on sodium affected soils
- soil salinization and/or discharge of saline water tables at or near the soil surface downslope from saline seep recharge areas

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all land uses where one or more of the following conditions exist:

- The concentration or toxicity of salt limits the growth of desirable plants
- Excess sodium causes crusting and permeability problems
- Saline seep recharge and discharge areas

CRITERIA

General Criteria Applicable to All Purposes

Localized ponding that persists for more than 24 hours after irrigation or precipitation events shall be alleviated by improvements to surface drainage.

In crop areas, shallow water tables shall be maintained below depths that cause salt accumulation in the root zone. Where depth to shallow water cannot be maintained by proper irrigation water management or by cropping practices, drainage shall be improved by one or more of the following:

- Interception and diversion of the subsurface inflows.
- Subsoiling where internal soil drainage is restricted by layers of contrasting permeability and soil moisture levels are low enough to allow shattering and mixing of soil layers.
- Installation of surface and/or subsurface drainage systems.

All work, including associated practices for management of drainage and runoff, shall comply with Federal, State, and local laws and regulations.

Identifying Salinity and Sodic Soil

Saline Soils

Naturally developed saline soils usually represent only small areas of a field but can extend to larger areas. Often, these areas are found in bottomlands which have poor internal drainage and a shallow water table. Other small areas occur on slopes where erosion has exposed saline subsoil. Soil surveys often indicate the location and extent of saline soils.

Capillary rise from the shallow water table carries soluble salts occurring in the soil or bedrock to the surface. The water evaporates on the soil surface and leaves behind salts.

These soils are also frequently wet during cultivation and can become compacted in and around the wet areas. Surface water will not move easily through the compacted soil, so more water evaporates on the surface leaving the salts to accumulate and the affected area to get larger with time. A very thin white crust will develop on the soil surface as the soil dries.

Crop production is reduced in these areas due to the salt accumulation. Seedling plants are very sensitive to water stress which leads to stand reduction.

Saline soils generally have a very good soil physical condition throughout the tillage depth. When these soils are not too wet, they are friable, mellow, and easily tilled.

Soil which has been saline for several years will have the following characteristics:

- Fertile and high in N, P, and K. Nutrients build up in salty areas because of limited crop growth and removal over time.
- Soil pH is less than 9.
- Electrical Conductivity (EC) of the soil extract is greater than 4 millimhos (mmho/cm) at 25°C. The EC is generally consistent throughout the soil profile.
- Sodium Adsorption Ratio (SAR) is less than 13.
- Exchangeable Sodium Percentage (ESP) is less than 15%.

Sodic (Alkali) Soils

Sodic soils contain excessive amounts of sodium. This can result from excess sodium in the subsoil by mineral weathering or sodium rich water applied to the surface.

Sodium forces the soil particles to separate and causes the soil to disperse. Sodic soils are not friable and mellow like saline soils. Instead sodic soils are greasy when wet, especially if it is fine textured and often very hard when dry. They are often characteristically too wet or too dry for tillage. Therefore, poor seed germination and stand establishment are common because good seedbed preparation is difficult.

The pores in the soil which allow water to infiltrate become plugged with the dispersed clay and organic material. As a result, the subsoil is very dry even though water is ponding on the surface. Plants in the area often suffer water stress and may eventually die from lack of water and oxygen.

The dispersed clay or organic material floating in the water remains on the soil surface after the water evaporates. The surface soil color will be darker when organic material is left and lighter in color when clay and salts are left after the surface dries.

Alkali soils will have the following characteristics:

- Exchangeable Sodium Percentage (ESP) greater than 15%.
- Sodium Adsorption Ratio (SAR) greater than 13.
- pH greater than 9.
- Electrical Conductivity (EC) of the soil extract is less than 4 millimhos (mmho/cm) at 25°C.

Saline – Sodic Soils

Saline – Sodic soils will have the following characteristics:

- Exchangeable Sodium Percentage (ESP) greater than 15%.
- Sodium Adsorption Ratio (SAR) greater than 13.
- pH greater than 9.

Induced Saline or Sodic (Alkali) Soils

Saline and/or sodic soils can be induced with liquid wastes from saltwater brine released from oil wells.

Saltwater brine is concentrated sodium chloride along with other salts and possibly toxic elements. It can result from seepage of evaporation ponds, leakage from wells and pipelines or from unloading tank trucks at the site.

These sites have soils that are dispersed, have a white crust and are mostly bare of vegetation. Soil erosion is generally active at the site which has exposed the subsoil.

Determination of Saline and Sodic Soils

Saline and sodic soils have similar characteristics and can be confused with each other. Verifying the soil condition present is best done with soil testing.

Problem areas shall be evaluated in one of the following ways:

- A soil scientist will evaluate the site with a salinity meter, or
- Soil samples will be taken and tested for salinity at the Oklahoma State University soils lab or any other soils lab using the same testing procedures and approved through the North American Proficiency Testing Program.

Soil samples will be collected in accordance with OSU Fact Sheet PSS-2207 – How to Get a Good Soil Sample. Suspected areas should be sampled separately from the rest of the field. A salinity management analysis will be done on the soil sample. This analysis includes results for Na, Ca, Mg, K, B, EC, TSS (total soluble salts), Sodium Adsorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), and pH. It is best to sample during a dry period of the growing season and should be taken at least one week after the last rain. Samples should only be taken from the top 1 to 3 inches of soil (seeding depth).

Whenever the source of the salt or sodium is external, such as brine from oil wells, eliminate the source as soon as possible.

Apply conservation practices as needed to control erosion on the site.

Criteria Applicable to Irrigated Lands

Irrigation water shall be applied according to the NRCS National Engineering Handbook, Part 652, Irrigation Guide and the Oklahoma NRCS Irrigation Water Management (449) standard.

Soil electrical conductivity in the plant root zone shall be measured to determine the depth of water application necessary for flushing accumulated salts and maintaining a proper salt balance.

The suitability of applied water for irrigation and leaching shall be based on a representative water quality test report that includes electrical conductivity (EC), sodium adsorption ratio (SAR), and pH as well as the concentrations of the following individual constituents: calcium, magnesium, sodium, and sulfate concentrations.

The volume of irrigation water applied shall include the leaching fraction necessary to maintain root zone salinity and sodium levels within acceptable levels for crops and for soil quality. Leaching fractions shall be determined using methods in the National Engineering Handbook, Part 623, Chapter 2, Irrigation Water Requirements.

Using effluent water for irrigating crops and grasses can increase salt concentrations in the soil creating a negative impact on plant growth. Oklahoma Technical Note Agronomy OK-17 contains guidance for irrigating with effluent water.

Criteria Applicable to Non-irrigated Lands

Reclamation shall utilize vegetative methods, soil amendments, and/or enhanced drainage to effect a reduction in soil salinity.

Improve Internal Soil Drainage

Salt concentrations in the soil profile must be reduced in the plant root zone. Internal drainage in the soil profile must be good enough so that water can easily pass through the soil to leach salts out of the root zone.

There are a number of ways internal drainage can be improved. Tile drains and open ditches are effective in lowering subsoil water that accumulates above compacted clay and bedrock zones. The water table needs to be lowered to a minimum of 6 ft. below the soil surface for clays and loams and 4 ft. for sandy loams or lighter textured soils.

Compacted soil layers near the soil surface need to be broken up by using deep tillage implements. The soil has to be dry enough to have a shattering effect on the hardpan layer. Refer to guidance in the Oklahoma NRCS Deep Tillage (324) standard.

Incorporate Organic Material

Once internal drainage is assured, the water movement into the soil must be improved. Incorporating 15 to 20 tons/ac of organic material into the top 4 to 6 inches creates large pore space for water to enter the soil. Organic material will be applied according to the Oklahoma NRCS Mulching (484) standard under the criteria for improving soil condition and fertility - saline and alkali soil.

Tillage and Planting of Saline and Sodic Soils

Inversion type tillage, such as moldboard plowing, should be avoided for several years to promote uninterrupted leaching of the salts through the soil profile. Inversion tillage brings soil and salts from the depth of tillage up to the soil surface and starts the leaching process over again. Avoid tillage when the risk for compacting the soil is high on problem areas.

When the salt level in the soil has been reduced adequately, a salt tolerant crop or forage can be established on the problem area. Refer to the Oklahoma Technical Note Agronomy OK-17, Table 1, for salt tolerances of crops and forages.

Grass plantings will be done according to the Oklahoma NRCS Critical Area Planting (342) standard. Select species that can be established in the existing salinity.

It is especially important to have a crop or cover on the soil surface during the summer when evaporation is high. The surface should be kept covered as much as possible to keep moisture from evaporating and groundwater from wicking to the surface bringing up salts.

Use soil testing to avoid applying excess fertilizer. Fertilizers contain salts and if applied in excess can add to the problem. Apply fertilizer according to the Oklahoma NRCS Nutrient Management (590) standard.

Criteria to Reduce Problems of Crusting, Permeability or Soil Structure on Sodium-affected Soils.

Management for saline and sodium soils is the same to this point. Sodic soils will require additional treatment.

Apply Gypsum to Sodic (Alkali) Soils

For the root zone profile, soil tests from each quarter of the root zone shall report electrical conductivity (EC); hydrogen ion concentration (pH); exchangeable sodium percentage (ESP); and ion concentrations of sodium, calcium, magnesium, and sulfate-sulfur.

The need for soil amendments to treat sodium affected soils shall be based on the sodium adsorption ratio of the soil water extract. Soil amendments shall be of a type that causes replacement of adsorbed soil sodium by calcium.

Application rates for soil amendments shall be based on SAR soil test results from the depth of the root zone to be treated; the purity of the applied amendment; and quality of the irrigation water.

Sodium is attached to soil particles very tightly and must be replaced before it can be leached through the soil. Gypsum is the most effective soil amendment for removing sodium from the soil. It is a slightly soluble salt of calcium and sulfate. Gypsum will react with the sodium in the soil very slowly but for a long period of time.

The amount of gypsum required varies depending on the percent of exchangeable sodium and soil texture as shown in the table below.

Soil Texture	Exchangeable Sodium				
	15	20	30	40	50
	Tons per acre Gypsum				
Coarse	2	3	5	7	9
Medium	3	5	8	11	14
Fine	4	6	10	14	18

Incorporate the gypsum to a depth of only 1 or 2 inches in the soil. It should be mixed well enough with the soil to keep it from blowing away.

When the application of gypsum exceeds 5 tons/ac, the rate should be split into two or more applications of no more than 5 tons per application. Successive applications should not be made until sometime has allowed for leaching to occur (1 year) and a second soil test verifies the need for the additional application of gypsum.

Criteria Specific to Saline Seeps and their Recharge Areas

Mitigation shall include vegetative measures to reduce subsurface water and salt movement from the recharge area to the discharge area. Vegetative measures include establishment of deep rooted perennial crops such as wheatgrass and the deeper rooted cultivars of alfalfa.

The following measures shall be applied to reduce subsurface water and salt movement to the seep outlet:

- Establish deep-rooted, long season species in the recharge watershed area to utilize soil moisture and limit ground water movement to the seep area.

- Remove ponded surface water from the recharge area before it percolates below the root zone.
- Where practical, re-vegetation of the saline seep discharge area shall be accomplished with species adapted to utilize excess soil moisture and to prevent up flux of water and salts.

Identifying Saline Seeps

Saline seeps are intermittent or continuous saline water sites that discharge at the soil surface. They occur downslope from a recharge area.

Saline seeps will develop white crusts on the soil surface as water evaporates from the soil profile during dry periods. Normal crop growth is inhibited due to the salt concentration in the plant root zone. Seed germination and early seedling stages are particularly affected.

Saline seeps will also have a very good physical condition throughout the tillage zone. The soil will be friable, mellow, and easily tilled. Soil which has been saline for several years is generally very fertile having high N, P, and K soil analysis. These nutrients tend to build up due to the lack of vegetation grown on the site.

Determination of Saline Seeps

Saline seeps shall be evaluated in one of the following ways:

- A soil scientist will evaluate the site with a salinity meter, or
- Soil samples will be taken and tested for salinity at the Oklahoma State University soils lab or any other soils lab using the same testing procedures and approved through the North American Proficiency Testing Program.

The size of the recharge and seep area will be determined by a soil scientist and delineated on an aerial map. Recharge areas are generally within 2000 ft. of the saline seep.

Saline seeps have the following characteristics:

- They have been accelerated by dryland farming practices.
- They are recent and local in origin.
- They develop a white crust on the soil surface.
- The water table is within 8 feet of the soil surface (often within 3 ft. of the soil surface).
- Soil Electrical Conductivity (EC) is greater than 4 millimhos (mmhos/cm) at 25^{o}C in the top 6 inches of soil. The soil EC will decrease with soil depth.
- Soil pH is less than 9.
- Groundwater salinity is generally 4000 micromhos or greater (2600 ppm soluble salts).

Management of the Recharge Area

Saline seeps are caused by water escaping the plant root zone in the recharge area and moving downslope until surfacing.

Plant and maintain adapted high water use vegetation in recharge areas to utilize soil water before it escapes the root zone. At least 80% of the recharge area should be planted to perennial vegetation.

Grass plantings in recharge areas will be done according to the Oklahoma NRCS Pasture and Hay Planting (512) and Range Planting (550) standards.

Where practical, divert run-on water and/or install surface and/or subsurface drainage to minimize water infiltration and decrease soil water in recharge areas.

Management of Saline Seep Area

Plants that produce satisfactory yields under the existing salinity should be used in the seep area. Adapted vegetation may be established in saline seep areas at the same time as the recharge area, however, it is best to delay planting until water tables have been lowered sufficiently to prevent capillary movement of water and salts into the root zone and to the soil surface.

Refer to the Oklahoma Technical Note Agronomy OK-17, Table 1, for salt tolerances of crops and forages.

Grass plantings in saline seep areas will be done according to the Oklahoma NRCS Critical Area Planting (342) standard.

CONSIDERATIONS

Tools such as electromagnetic induction (EMI), salinity probes (i.e. four electrode Wenner array), electrical conductivity instruments, and field soil test kits are appropriate for evaluating and for monitoring soil salinity levels.

Representative water chemistry reports for surface water sources may be available from USGS or from water districts.

Rigorous irrigation water quality tests for potassium, chloride, bicarbonate, and carbonate levels may be warranted in areas of high concern.

Consult published data for crop salt tolerances, and specific ion toxicities of crops for crop recommendations.

Local conditions and specific crop ion sensitivities may warrant water quality analysis for toxic salts (boron, chloride, etc.).

Sulfur or sulfuric acid applications enhance conversion of naturally occurring calcium carbonate to more soluble gypsum. Leaching should be delayed until the sulfur has oxidized and gypsum has formed.

Applications of a soluble calcium source such as gypsum in combination with irrigation leaching applications will help in displacing sodium from the root zone.

Seasonal changes in source water quality may require water quality evaluations at several times during the season of use.

Drainage water discharges may have high concentrations of salt. Select appropriate outlets and consider effects to surface water and groundwater.

Subsoiling for improvement of internal soil drainage may not be effective in soils of uniform texture/permeability, or if soils are not dry during subsoiling operations.

Avoid inversion tillage that can bring salinity to the surface and negate the leaching process.

Incorporation of green manure crops or organic matter into the soil can improve soil structure and permeability.

Salt tolerant crops with vigorous growing, fibrous root systems (e.g. sorghum, sudangrass) can increase the carbon dioxide content of the soil water, increasing the solubility of calcium carbonate to facilitate leaching of sodium.

For leaching of salts, water of slight to moderate salinity not dominated by sodium can be more effective than water of low salinity.

Crop residue management can improve the organic matter content of the soil, improve infiltration, and minimize surface evaporation and capillary rise of salts to the soil surface.

Select crop bedding shapes and planting methods that reduce the concentration of salinity near the plant root zone, especially for germinating seeds.

Foliar damage can be an indicator of specific ion toxicities.

PLANS AND SPECIFICATIONS

Specifications for establishment and operation of this practice shall be prepared for each field or treatment unit according to the Criteria described in this standard and shall include the following items as applicable:

- Plan map showing location of:
  - Salinity/sodium affected areas
  - Saline seep recharge areas
  - Saline seep outlets or discharge areas.
- Geologic investigation showing:
  - location (depth, extent) of materials contributing to salinity/sodicity on saline seep recharge areas
  - impervious layers that cause hillside seeps.
- Soil tests required to determine current soil salinity/sodicity, plus previous test results to evaluate the effectiveness of the planned treatment and potential need for revision.
- Water tests required to determine suitability for irrigation and leaching.
- Leaching requirements for specific soils and crops, including the method and timing of water application.

REFERENCES

USDA-NRCS, National Engineering Handbook, Part 623, Chapter 2, Irrigation Water Requirements.

OSU Extension Fact Sheet PSS-2226, “Reclaiming Slick-Spots and Salty Soils”.